DEVELOPMENT OF AN ERGONOMIC RISK ASSESSMENT TOOL FOR WORK POSTURES

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ABSTRACT

The most widely used method for assessing work-related musculoskeletal disorders (WMSDs) is still the observational method, mainly because it is inexpensive and practical for use in a wide range of workplaces. However, there are no tools available that cover the wide range of physical risk factors at workplaces. Most of the existing observational methods have not been extensively tested for their reliability and validity during the development process. Therefore, the main objectives of this study are to (1) to develop a new observational technique called the Workplace Ergonomic Risk Assessment (WERA) method and (2) to determine the reliability and validity of the WERA method. The study was conducted in two phases: development of the WERA paper checklist from scientific evidence and literature review (Phase 1) and development of the WERA software program using Visual Basic programming (Phase 2). In the validity trials, the relationship of the main WERA body part scores to the development of pain or discomfort was statistically significant for the wrist, shoulder, and back regions. This shows that the WERA assessment provided a good indication of work related musculoskeletal disorders which may be reported as pains, aches or discomfort in the relevant body area. In the reliability trials, the results of inter-observer reliability demonstrated moderate agreement among the observers (K=0.41) from the feedback survey about the usability of WERA tool. On the other hand, all participants were agreed that the WERA tool was easy and quick to use, applicable to workplace assessment for the wide range of tasks, and valuable at work. The WERA tool has been developed for both paper checklist and software program use. It can be used to identify the physical risk factors associated with WMSDs at workplaces.

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ABSTRAK

Kaedah yang paling banyak digunakan untuk menilai kerja yang berkaitan dengan gangguan otot berangka (WMSDs) adalah kaedah pemerhatian, ini kerana ianya adalah murah dan praktikal untuk digunakan di pelbagai tempat kerja. Walau bagaimanapun, alat yang sedia ada tidak merangkumi pelbagai faktor risiko fizikal di tempat kerja. Tambahan pula, kebanyakan kaedah pemerhatian yang sedia ada didapati tidak diuji secara meluas tentang kebolehpercayaan dan kesahihannya semasa proses pembangunan kaedah tersebut. Oleh itu, objektif utama kajian ini adalah untuk (1) untuk membangunkan satu teknik baru dalam kaedah pemerhatian yang dinamakan sebagai kaedah *"Workplace Ergonomics Risk Assessment – WERA"* (2) untuk menentukan kebolehpercayaan dan kesahihan kaedah WERA. Kajian ini telah dijalankan dalam dua fasa iaitu pembangunan kertas senarai semak WERA hasil dari bukti saintifik kajian literatur (Fasa 1) dan pembangunan program perisian WERA yang menggunakan asas pengaturcaraan visual (Fasa 2). Dalam ujian kesahihan, hubungan diantara skor WERA dengan ketidakselesaan pada bahagian utama anggota badan adalah statistik yang signifikan bagi kawasan pergelangan tangan, bahu dan belakang badan. Ia menunjukkan bahawa kaedah WERA memberikan indikasi yang baik terhadap kerja yang berkaitan dengan gangguan otot berangka yang boleh menyebabkan ketidakselesaan ataupun kesakitan anggota badan tertentu. Dalam ujian kebolehpercayaan, keputusan kebolehpercayaan antara pemerhati menunjukkan bahawa nilai persetujuan di antara pemerhati adalah sederhana (K=0.41) manakala hasil maklum balas daripada soal selidik mengenai kebolehgunaan kaedah WERA, semua peserta telah bersetuju bahawa kaedah WERA ini mudah dan cepat untuk digunakan serta sesuai dan bernilai untuk digunakan di pelbagai tempat kerja. Dengan membangunkan kertas senarai semak WERA dan program perisian WERA, diharapkan ianya boleh digunakan untuk mengenal pasti faktor-faktor risiko fizikal yang berkaitan dengan gangguan otot berangka di tempat kerja.

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LIST OF ABBREVIATIONS

Back-EST	-	Back Exposure Sampling Tool
BDS	-	Body Discomfort Survey
DOSH	-	Department of Occupational Safety and Health
LUBA	-	Postural Loading on the Upper-Body Assessment
MSDs	-	Musculoskeletal Disorders
NIOSH	-	National Institute of Occupational Safety and Health
OSHA	-	Occupational Safety and Health Administrative
OWAS	-	Ovako Working Posture Assessment System
PATH	-	Posture, Activity, Tools & Handling
QEC	-	Quick Exposure Check
REBA	-	Rapid Entire Body Assessment
RULA	-	Rapid Upper Limb Assessment
SHO	-	Safety and Health Officer
SPSS	-	Statistical Package for the Social Sciences
WERA	-	Workplace Ergonomic Risk Assessment
WMSDs	-	Work-related Musculoskeletal Disorders

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LIST OF SYMBOLS

K	-	Cohen's Kappa Coefficient
N	-	Sample Size
SD	-	Standard Deviation
X	-	Mean
°	-	Degree
±	-	Plus-Minus
%	-	Percentage
α	-	Alpha
χ^2	-	Chi Square
p	-	Pearson Chi-Square
r	-	Spearman Correlation Coefficients

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CHAPTER 1

INTRODUCTION

1.1 Overview of the Study

Ergonomics is the one of main components of safety programs around the country, and many companies have begun implementing effective ergonomic programs in their workplaces (Brodie, 2008). A basic ergonomic assessment is often the starting point for a company to approach implementing such a program due to the ergonomics hazards at a workplace (Brodie, 2008; Burdorf, 2010). This approach helps the company determine whether the jobs or tasks expose employees to risk factors that could lead to musculoskeletal disorders (MSDs). By determining how the job exposes employees to ergonomic risk factors, this approach helps the company reduce the cost of occupational injuries and work-related illnesses (Li and Buckle, 1999a; Li and Buckle, 1999b; David, 2005; Brodie, 2008; Burdorf, 2010). An additional reason to invest in ergonomics at the workplace is that it helps improve the productivity of employees, which can result in increased bottom line profits of a company (Brodie, 2008; Burdorf, 2010).

Benefits from the use of ergonomics are important to industries, so an ergonomic assessment should be the first step taken in the process of safety and health assessment (Brodie, 2008; Burdorf, 2010; Takala *et al*., 2010). The rationale for this study grew out of research needs for practical methods used to define and evaluate the ergonomics risk factors present in a job associated with work-related musculoskeletal disorders (WMSDs). It is important to identify the ergonomics stressors linked with development of WMSDs, which are key elements for any ergonomics program in developing the assessment of biomechanical exposure in workplaces (Li and Buckle, 1999a; Li and Buckle, 1999b; David, 2005; Brodie, 2008;

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Burdorf, 2010). The accurate measurement of workers' exposure to the risk factors related to WMSDs are critical to both epidemiologists and ergonomists in conducting their research studies (David, 2005; Burdorf, 2010).

Work-related musculoskeletal disorders (WMSDs) are a common health problem and a major cause of disabilities (Hales and Bernard, 1996; Bernard, 1997; Kuorinka, 1998; Malchaire *et al.*, 2001). A range of physical, individual, and psychosocial risk factors are associated with the development of WMSDs. Physical risk factors are based on exposure to physical demands while performing tasks; these factors include awkward posture, forceful exertion, repetition of movement, contact stress, vibration, and task duration (Bernard, 1997; Malchaire *et al*., 2001; Aptel *et al*., 2002; Punnett and Wegman, 2004). Recent studies have shown that the effects of WMSDs result in productivity loss at work, sickness, absence, and disability (Bernard, 1997; Aptel *et al*., 2002; Punnett and Wegman, 2004). According to the Department of Occupational Safety and Health (DOSH) report on occupational accidents for the category of death until August 2010 (Figure 1.1), 51% of victims were reported by the construction industry, the highest figure. The manufacturing industry was the second highest, for which 45% of victims were reported, behind the agriculture industry (26% of victims) and the transportation industry (10% of victims) (DOSH, 2010).

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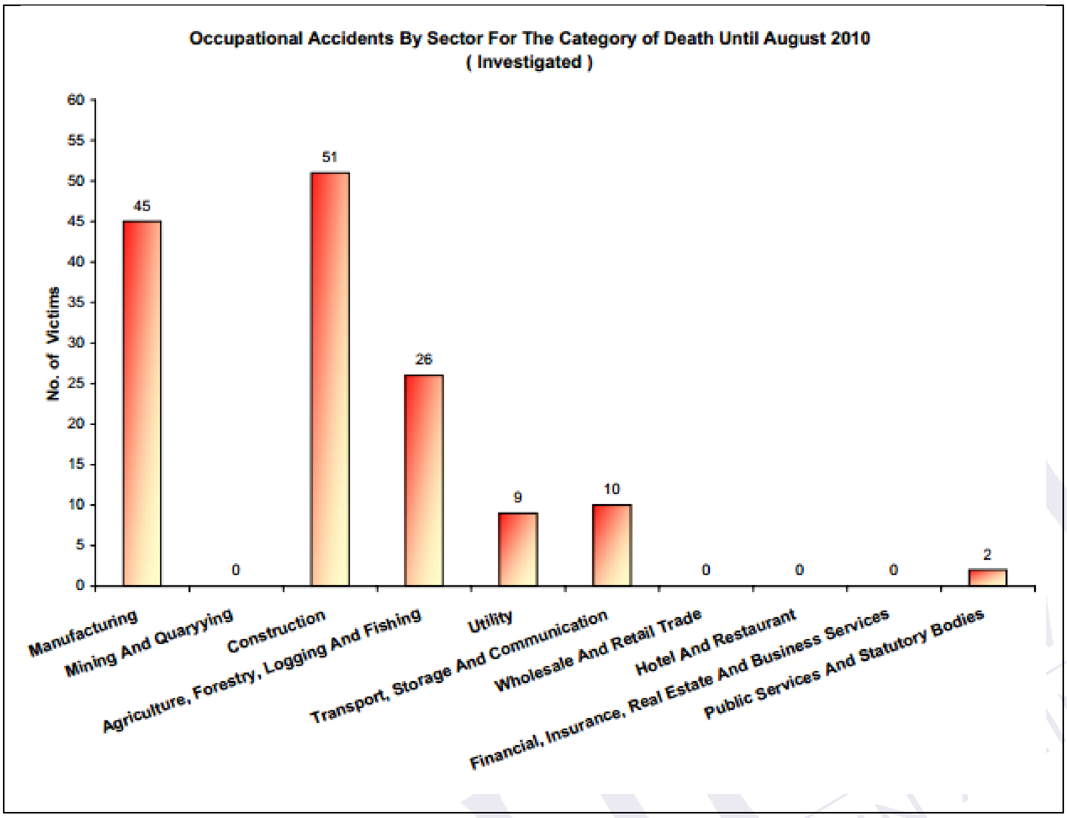

Figure 1.1 Occupational accidents by sector for the category of death until 2010

Musculoskeletal injuries begin with the workers experiencing discomfort or pain due to their tasks at a workplace (Hales and Bernard, 1996; Kuorinka, 1998; Malchaire *et al.*, 2001; Devereux *et al.*, 2002; Punnett and Wegman, 2004; Khan *et al.*, 2010). Due to the risk factors present at workplaces, the discomfort will lead to an increase in the severity of symptoms and will be experienced as aches and pains (Devereux *et al.*, 2002; Punnett and Wegman, 2004; Khan *et al.*, 2010). The aches and pains may eventually result in musculoskeletal injuries such as low back pain, tendonitis, or serious nerve-compression injury such as carpal tunnel syndrome (Malchaire *et al.*, 2001; Aptel *et al.*, 2002; Punnett and Wegman, 2004).

1.2 Problem Statements

Current techniques to assess the exposure of the risk factors related to WMSDs still utilize observational methods, mainly because they are inexpensive and practical for use in a wide range of workplaces whereas using the other methods would be difficult due to the disruption they would cause (Beek and Dressen,1998; Li and Buckle, 1999a; David, 2005; Brodie, 2008; Takala *et al.*, 2010).

However, there is no tool available to covers the wide range of physical risk factors in the workplace (Table 1.1), which include posture, repetition, forceful exertion, vibration, contact stress and task duration (David, 2005; Takala *et al*., 2010). There is a need to widen the existing range of physical risk factors and to consider the interactions among them (David, 2005). Most of the observational tools available only focus on postural assessments of various body parts rather than covering the critical physical exposure factors in the workplaces (David, 2005; Burdorf, 2010; Takala *et al.*, 2010).

Table 1.1: Risk factors assessed by different assessment methods

Method (Year of First Publication)	**Risk Factors**					
	Posture	**Forceful Exertion**	**Repetition**	**Vibration**	**Contact Stress**	**Task Duration**
Ovako Working Posture Assessment System – OWAS (1977)	×	×				
Rapid Upper Limb Assessment – RULA (1993)	×	×				
Posture, Activity, Tools & Handling – PATH (1996)	×	×		×		
Quick Exposure Check – QEC (1999)	×	×	×			×
Rapid Entire Body Assessment – REBA (2000)	×	×				
Postural Loading on the Upper Body Assessment – LUBA (2001)	×					
Back Exposure Sampling Tool – BackEst (2009)	×	×		×		

(Sources: David, 2005; Takala *et al*., 2010)

Furthermore, most of the existing observational methods have not been extensively tested due to infrequent assessments of reliability and validity (Table 1.2) during the development process of the tools (David, 2005; Brodie, 2008; Burdorf,

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2010; Takala *et al.*, 2010). The evaluation of reliability and validity are critical to the development of ergonomic exposure assessment tools, particularly for research that attempts to establish a causal relationship between ergonomic risk factors and musculoskeletal health outcomes (David, 2005; Burdorf, 2010; Takala *et al.*, 2010). Takala *et al.* (2010) stated that a major challenge in developing an observational tool is the validation of exposure assessment techniques. Poor performance of exposure assessment tools due to the lack of reliability and validity testing contributes to the scepticism regarding the work-relatedness of musculoskeletal disorders (David, 2005; Takala *et al.*, 2010).

Table 1.2: Reliability and validity studies of different assessment methods

Method (Year of First Publication)	**Psychometric Properties**	
	Reliability Testing	**Validity Testing**
Ovako Working Posture Assessment System – OWAS (1977)	×	-
Rapid Upper Limb Assessment – RULA (1993)	×	×
Posture, Activity, Tools & Handling – PATH (1996)	×	×
Quick Exposure Check – QEC (1999)	×	-
Rapid Entire Body Assessment – REBA (2000)	×	-
Postural Loading on the Upper Body Assessment – LUBA (2001)	-	×
Back Exposure Sampling Tool – BackEst (2009)	×	-

(Sources: David, 2005; Takala *et al.*, 2010)

Therefore, this research aims to develop a new type of ergonomic risk assessment tool that covers both the range of the physical risk factors associated with WMSDs and establishes the reliability and validity of the tool during the development process.

1.3 Objectives of the Study

The main objectives of this research are:

i. To develop a new ergonomic risk assessment technique which assesses the exposure of physical risk factors associated with WMSDs.
ii. To establish the reliability and validity of the ergonomic risk assessment tool during the development process.
iii. To evaluate the application of the ergonomic risk assessment tool on different tasks.

The specific objectives of this research are:

a. To develop the ergonomic risk assessment paper checklist (Phase 1) and to test its reliability and validity during the development process.
b. To determine the validity of the ergonomic risk assessment tool that corresponds with other valid methods in the workplace. A comparative study will be performed using the Body Discomfort Survey.
c. To investigate the inter-observer reliability of observers assessing the physical risk factors of workers performing tasks using the ergonomic risk assessment tool.
d. To develop the ergonomic risk assessment software program (Phase 2) based on the ergonomic risk assessment paper checklist in Phase 1.
e. To verify that the ergonomic risk assessment software program corresponds with other valid methods in the workplace. A comparative study will be performed using the Body Discomfort Survey.

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1.4 Research Questions

1) How valid is the ergonomic risk assessment tool in the workplace? Does the ergonomic risk assessment tool correspond to the Body Discomfort Survey?
2) How reliable is the ergonomic risk assessment tool between users and observers? Do the users and observers have good, moderate, or low levels of agreement when assessing the physical risk factors of tasks using ergonomic risk assessment tool?
3) How usable is the ergonomic risk assessment tool among the users and observers? Is the ergonomic risk assessment tool easy to use, applicable to the wide range of jobs, and valuable at work?

1.5 Scope of the Study

The scope of this research encompasses the development of the observational method, which is called the Workplace Ergonomic Risk Assessment (WERA) tool. This tool covers the physical risk factors associated with work-related musculoskeletal disorders (WMSDs) at workplaces; these factors include posture, repetition, lifting the load, vibration, contact stress and task duration. This tool assessed five main body regions: shoulders, wrists, back, neck and legs. This tool did not cover the specifics of environmental factors such as noise, lighting and thermal comfort since these factors focus more on the work environment and there already exist specific tools to evaluate these factors, such as the ACGIH Threshold Limit Value for Heat Stress and Strain (2006a) for thermal comfort risk factors, the ACGIH Threshold Limit Value for Noise (2006b) for noise risk assessment and the Cornell Task Lighting Evaluation (2007) for lighting risk assessment.

During the validity test, 130 workers (Male) from the ages of 20 to 44 years have been selected to perform three jobs in the construction industry, including wall plastering, bricklaying, and floor concreting. Case Study 1 involved 115 operators (female) ranging from the ages of 20 to 35 years selected to perform three jobs at Company A located in Tangga Batu Indutrial Estate, Melaka. The jobs were also in

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the manufacturing industry and included wafer sawing, wire bonding, and multi-plunging. Case Study 2 involved 118 operators (Female) from the ages of 20 to 35 years selected to perform three jobs at Company B located in Senawang Industrial Estate, Negeri Sembilan. These jobs in the manufacturing industry included inspection, transaction, and packaging job. This study focused on selection of participants of the working ages of 20 to 44 because the statistical data from the Bureau of Labor Statistics (2011) reported that workers who were 20 to 44 years of age had the highest incidence rate at 134 cases per 10,000 full-time workers in the construction and manufacturing industries. Department of Occupational Safety and Health (DOSH) reported that industries with the highest occupational accidents rates included the construction and manufacturing industries (DOSH, 2010). Therefore, the validity test and case studies have been focused on the construction and manufacturing industries. This research has aided in the development of two types of the WERA tool, the WERA paper checklist and the WERA software program.

1.6 Significance of the Study

The proposed method for this study will contribute to new knowledge in the ergonomic research field, especially to knowledge of methods in ergonomic exposure assessment tools. This is because the lack of well-designed exposure assessment methods is a primary issue for epidemiological studies of work-related musculoskeletal disorders (WMSDs) (David, 2005; Burdorf, 2010; Takala *et al.*, 2010). To date, no tool has been developed to cover the range of physical risk factors related to WMSDs which carried out reliability and validity studies during the development process of the tool. This is the first ergonomic risk assessment tool that meets the research needs for practical methods to evaluate and define the ergonomics risks inherent to a job, especially factors associated with WMSDs in the workplace.

The results of this study are useful to the development of new techniques of the observational tool called the Workplace Ergonomic Risk Assessment (WERA), which covers the range of physical risk factors related to WMSDs and addresses the reliability and validity studies during the development process of the tool. Critical information may be introduced to identify the ergonomics hazards that are linked

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with the development of WMSDs; it is key to examine these hazards as part of any ergonomics activity in developing the assessment of biomechanical exposure at the workplace.

In addition, assessing exposure to risk factors for WMSDs is an essential stage in the management and prevention of WMDSs, and such assessment may even form part of an overall risk assessment programme in the industry (David, 2005; Brodie, 2008; Burdorf, 2010; Takala *et al*., 2010). Well-designed observational tools that assess the physical risk factors related to the WMSDs have been of vital importance to both epidemiologists and ergonomists in conducting research studies (David, 2005; Brodie, 2008; Burdorf, 2010; Takala *et al.,* 2010).

1.7 Organization of the Thesis

This thesis contains seven chapters. The chapters are arranged according to the sequence of objectives and the rationale of the research. The seven chapters are: Chapter 1 (Introduction), Chapter 2 (Literature Review), Chapter 3 (Research Methodology), Chapter 4 (Development of the WERA Method), Chapter 5 (Results), Chapter 6 (Discussion) and Chapter 7 (Summary, Conclusions and Future Works).

Chapter 1 describes the background of the research, the objectives to be achieved, the research scope, the significance of the research and the organization of the thesis. Chapter 2 gives an overview of the literature and primarily focuses on the discussion of the ergonomic methods used in assessing work-related musculoskeletal disorders (WMSDs). These methods are divided into three main categories: self-report questionnaires, observational methods, and direct measurement techniques. Chapter 3 explains the research methodology and focuses on the development of the WERA method, the validity of the WERA method, the reliability of the WERA method, development of the WERA software program and verification of the WERA software program in two different case studies.

Chapter 4 describes details of the development of the WERA method, which is divided into two phases: development of the WERA paper checklist (Phase 1) and development of the WERA software program (Phase 2). Chapter 5 shows the results of the validity and reliability testing of the WERA method (Phase 1) and verification

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of the WERA software program (Phase 2). It is divided into six sections: introduction, validity testing of the WERA method, reliability of the WERA method, verification of the WERA software program by Case Study 1, and verification of WERA software program by Case Study 2. Chapter 6 discusses the findings from the Chapter 5, including the results of the validity and reliability testing of the WERA method (Phase 1) and verification of the WERA software program (Phase 2).

Chapter 7 concludes with the summary, further conclusions and future work on this research.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The review of the literature primarily focuses on the ergonomic methods used to assess work-related musculoskeletal disorders (WMSDs). It is divided into four sections: introduction, ergonomic methods for WMSDs, observational methods for WMSDs and conclusion. Section 2.2 discusses the commonly used exposure quantification ergonomic methods for WMSDs, which include self-report questionnaires, observational methods and direct measurement techniques. To identify the gaps of knowledge in this research, Section 2.3 presents details of the observational methods that have been developed for assessing WMSDs. This section is subdivided into seven sections that discuss the types of observational tools based upon several criteria. The inclusion criteria for selecting the observational tools were as follows: (1) the year of first publication in original scientific articles from 1977 to 2009; (2) objectives of the method; (3) range of physical risk factors covered by the method; and (4) the making of the method during the development process in term of reliability and validity studies. Based on these strategies, it would be useful for the researcher to develop a proposed method based on the gaps of knowledge in Section 2.4. Designing methodology for the development process on the proposed method is outlined in Chapters 3 and 4.

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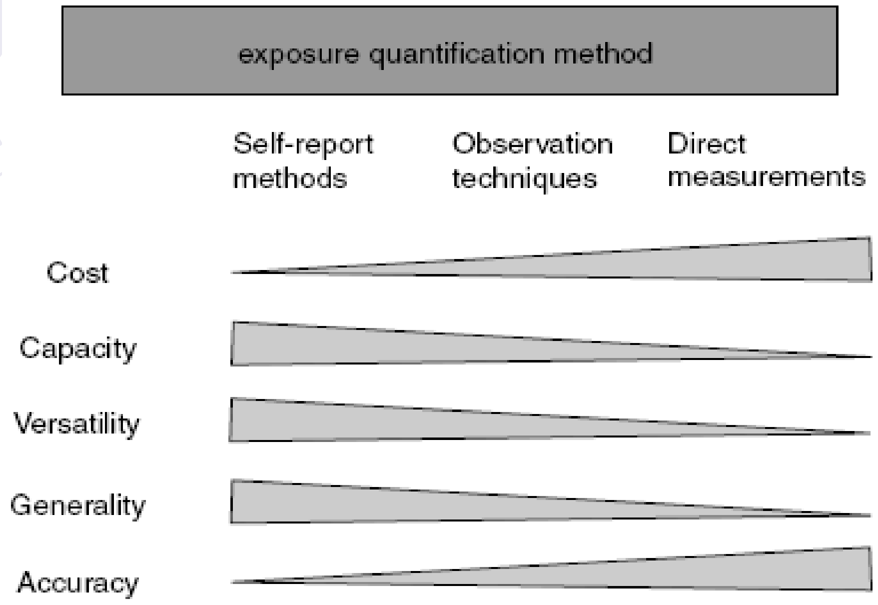
2.2 Ergonomic Methods for Work-related Musculoskeletal Disorders

Lower back pain and neck pain are categorised as work-related musculoskeletal disorders (WMSDs), which are commonly experienced among workers (Hales and Bernard, 1996; Malchaire *et al.*, 2001; Punnett and Wegman, 2004). In a study by Bernard (1997), WMSDs became a serious health problem and a major cause of disabilities. WMSDs are caused by a range of physical, individual and psychological risk factors (Kuorinka, 1998; Punnet and Wegman, 2004). The physical demands include adaptation of work posture, forceful exertion, repetitive motion, vibration and task duration while performing a task (Bernard, 1997; Aptel *et al.*, 2002).

Commonly used exposure quantification ergonomic methods in work-related musculoskeletal disorder (WMSD) studies are divided into three categories: self-report questionnaires, observational methods and direct measurement techniques (Winkel and Mathiassen, 1994). Each method has its own strengths and weaknesses and may be used for different applications or purposes. Figure 2.1 illustrates some general characteristics of each method and may be used as a guide to select a method.



Source from Winkel and Mathiassen (1994)

Figure 2.1 Characteristics of the different methods

In general, direct measurement with instrumentation results in the most specific and accurate exposure estimation, but involves significant costs. This method would be impractical for individual exposure assessment in very large populations of large-scale epidemiological studies because of the significant resources and expertise that would be required. Self-reporting using questionnaires or interview methods can be used to assess large populations but the data obtained by these methods have low validity to the level of exposure. Observational measurement methods are frequently used in field studies as a compromise between questionnaire and direct measurement methods, since the former contains strengths and weaknesses of the latter. Observational methods present the best compromise for individual exposure assessment in large-scale epidemiological studies. The following sections discuss details of the ergonomic methods, such as self-report questionnaires, observational methods and direct measurement techniques.

2.2.1 Self-Report Questionnaires

Kadefors and Forsman (2000) stated that data collection on exposure of physical risk factors in the workplace using self-reports can be obtained from workers' diaries, interviews, and questionnaires. The most recent innovations in data collection using self-report are the written record, video film self-evaluation and the web-based questionnaires (Dane *et al.*, 2002). Other information can also be collected, such as demographic variables, signs and symptoms of body parts and signs of discomfort.

The advantages of these methods are that they are easy to use, can be applied to a wide range of working situations, and are suitable for surveying a large number of subjects. To ensure that the collection of data adequately represents the group of workers that are being investigated, a large sample size is needed. Accurate interpretation of the findings requires high-cost analysis and appropriate skills. Imprecise and unreliable worker perception of exposure presents a major problem for these methods. For example, reports of having experienced neck and back pain were found to increase the probability of workers reporting higher durations and

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frequencies of physical load compared to workers who were pain free in the same occupational groups (Viikari *et al*., 1996; Balogh *et al*., 2004).

The degree of difficulty of the self-report methods may vary depending on factors such as worker literacy, reading comprehension, or question interpretation (Spielholz *et al.*, 2001). Although the self-report methods generate doubt in quantifying the level of exposure (Pope *et al*., 1998), other methods can be used to analyse the details of exposure risk of the occupational group (Burdorf *et al*., 1999). The levels of reliability and validity of self-report methods are too low for use as the basis for ergonomics intervention at the workplace (Li and Buckle, 1999a).

2.2.2 Observational Methods

The most commonly used method is the observational method, which is applied to evaluate the ergonomic hazards at workplace, monitor the ergonomic improvements, and conduct research on ergonomic issues. Although this is the best method of approach, the density of the gathered data on ergonomic hazards is limited. The quantitative measurement of the exposure, risk and data can be tracked. The low cost of the assessment and its quick turnaround times are positive characteristics in the process of identifying ergonomics hazards in the workplace. A simple observational method can be used to recognize and control the ergonomic issues in the workplace. Section 2.3 discusses the details of the observational methods for work-related musculoskeletal disorders (WMSDs).

2.2.3 Direct Measurement Techniques

Attaching a sensor directly to the subject is one of the methods developed to measure the exposure variables in the workplace. Simple handheld devices and electronic goniometers can be used to obtain measurements and recordings of the range of motion while performing a task. To measure the rotation angles of fingers, wrists and forearm, a light-weight device commonly used to measure the articulating

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joint of the body part directly was developed (Biometric Ltd, 1998) together with corresponding systems for computerized data analysis (Radwin and Lin, 1993). Frievalds *et al*. (2000) developed the system, which recorded the concurrent movement of wrists, hand and fingers with grip pressure and directly connected to the computer. The Lumbar Motion Monitor is one of the tools developed to record body postures and movement assessment with combination appropriate software (Marras *et al*., 1992). It also used to record continuous data of three-dimensional components, including the trunk position, velocity and acceleration for subsequent analysis by computer (Hasson *et al*., 2001; Bernmark and Wiktorin, 2002). Li and Buckle (1999a) found that recording the body posture with the sensor attached to the worker's body is a technique to determine the time spent in different postures during working hour. For investigating the simulation of task, the computing systems that record the three-dimensional coordinates of all body markers are more suitable. Electromyography (EMG) is another direct method that can be used to estimate muscle tension, but it requires careful interpretation due to the non-linear relationships involved (Schuldt *et al*., 1987; Wells *et al*., 1997). Although it may difficult to interpret, it useful in evaluating the fatigue of local muscles (Merletti and Parker, 1999). Highly accurate data can be obtained by using this method, but many practitioners assume this method is still impractical because of the time needed for analysis and for interpreting the data. To purchase the direct measurement tools, the initial investment and other resources need to be considered to accommodate the maintenance costs and the costs of highly trained and skilled staff (Li and Buckle, 1999a).

2.3 Observational Methods for Work-related Musculoskeletal Disorders

Observational methods are often used to evaluate the ergonomic risk factors in the workplace. This method is commonly applied to identify ergonomic hazards due to its simple characteristics and its low costs. Figure 2.2 shows the evolution of the observational methods in practice from 1977 to 2009. The following sections discuss the details of the observational methods related to work-related musculoskeletal disorders (WMSDs) that have been published.

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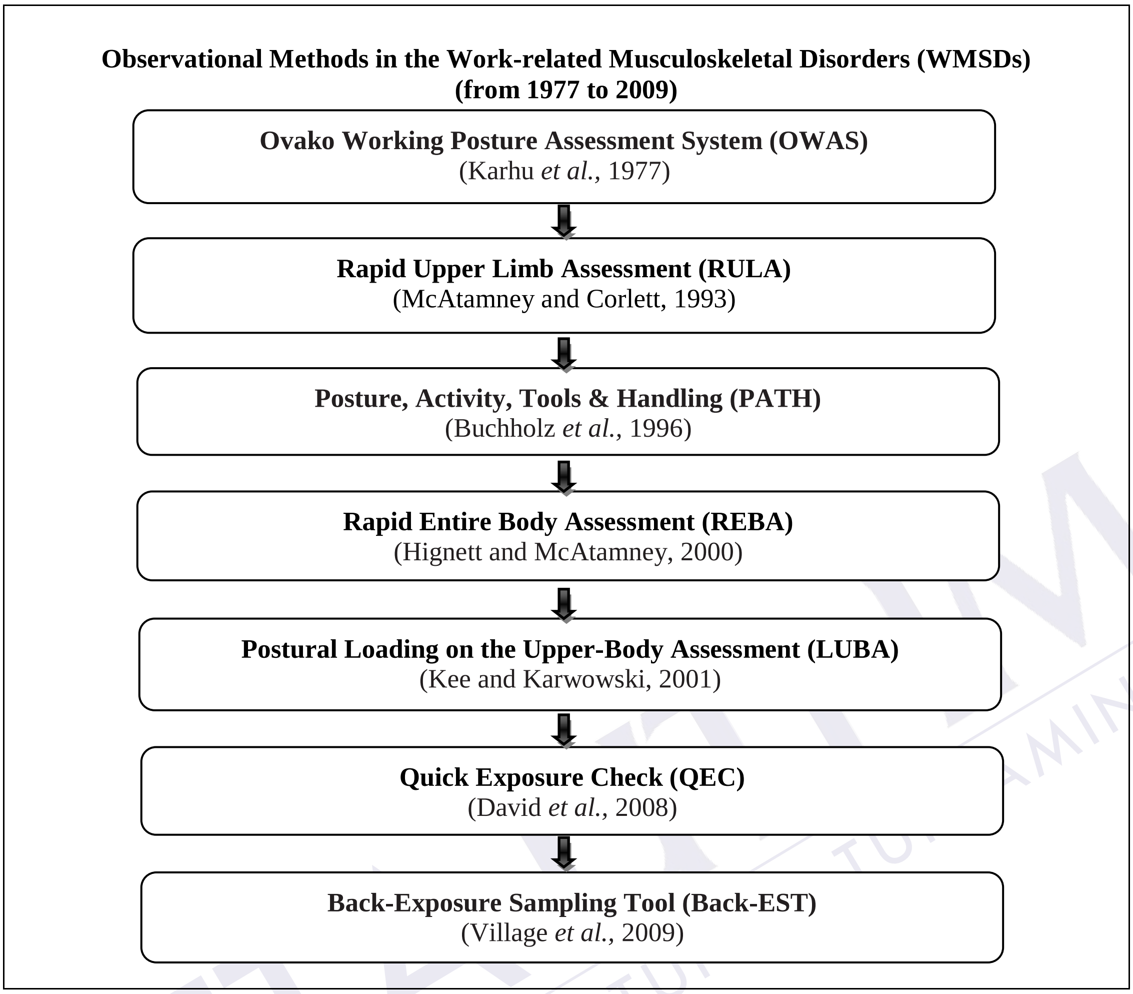

Figure 2.2 Observational methods for assessing the WMSDs from 1977 to 2009

2.3.1 Ovako Working Posture Assessment System (OWAS)

The Ovako Working Posture Assessment System (OWAS) was developed to identify and evaluate poor working postures in workplaces (Karhu *et al.*, 1977). The development of the OWAS tool has been conducted in the steel industry, which was used to define the various postures in workplaces such as the one adopted while overhauling iron smelting ovens. This method uses four digit-codes to describe the whole body posture involving back, arms, legs and the weight of the load handled. The range of risk factors includes posture and forceful exertion. There were two phases that occurred during the development of OWAS. The first phase was the classification of postures and the second phase was the evaluation of the defined postures.

Over 12 work-study engineers were trained to analyse the 28 tasks in the steel plant using the OWAS tool in order to prove the reliability of the OWAS method. The results were found to be fairly good with 93% agreement between the two groups of work-study engineers (Karhu *et al.,* 1977).

In conclusion, the OWAS tool was developed to identify and evaluate poor working postures in the workplace. In addition, the concept of its reliability may need more clarification. There is no formal study that has been conducted to determine its validity during its development process.

2.3.2 Rapid Upper Limb Assessment (RULA)

A survey method known as Rapid Upper Limb Assessment (RULA) was developed to analyse upper limb disorders which were related to work tasks (McAtamney and Corlett, 1993). Part of its development involved the operators, who performed five different tasks while standing in the garment making industry and were assessed using the RULA tool. The evaluation of exposure risk factors was based on a diagram of body posture and three scoring tables were provided. In this method posture and forceful exertion risk factors are covered. Three stages were involved in the development of the RULA tool: the working posture recording, the scoring system and the scale of action levels.

Sixteen experienced operators who performed VDU-based data entry tasks were assessed using the RULA in order to establish its validity. From this experiment, body part scores showed that neck and lower arm scores were found to be statistically significant ($P < 0.01$) while trunk, upper arm, and wrist scores were not significant. More than 120 professional practitioners including physiotherapists, industrial engineers and safety and production engineers were trained to test the reliability of the RULA tool using videotape examples of operators performing screen-based keyboard operations as well as packing, sewing and brick sorting tasks. The results showed that scoring among the subjects had high consistency. There was a moderate level of agreement for inter-observer reliability and validity in the workplace (McAtamney and Corlett, 1993).

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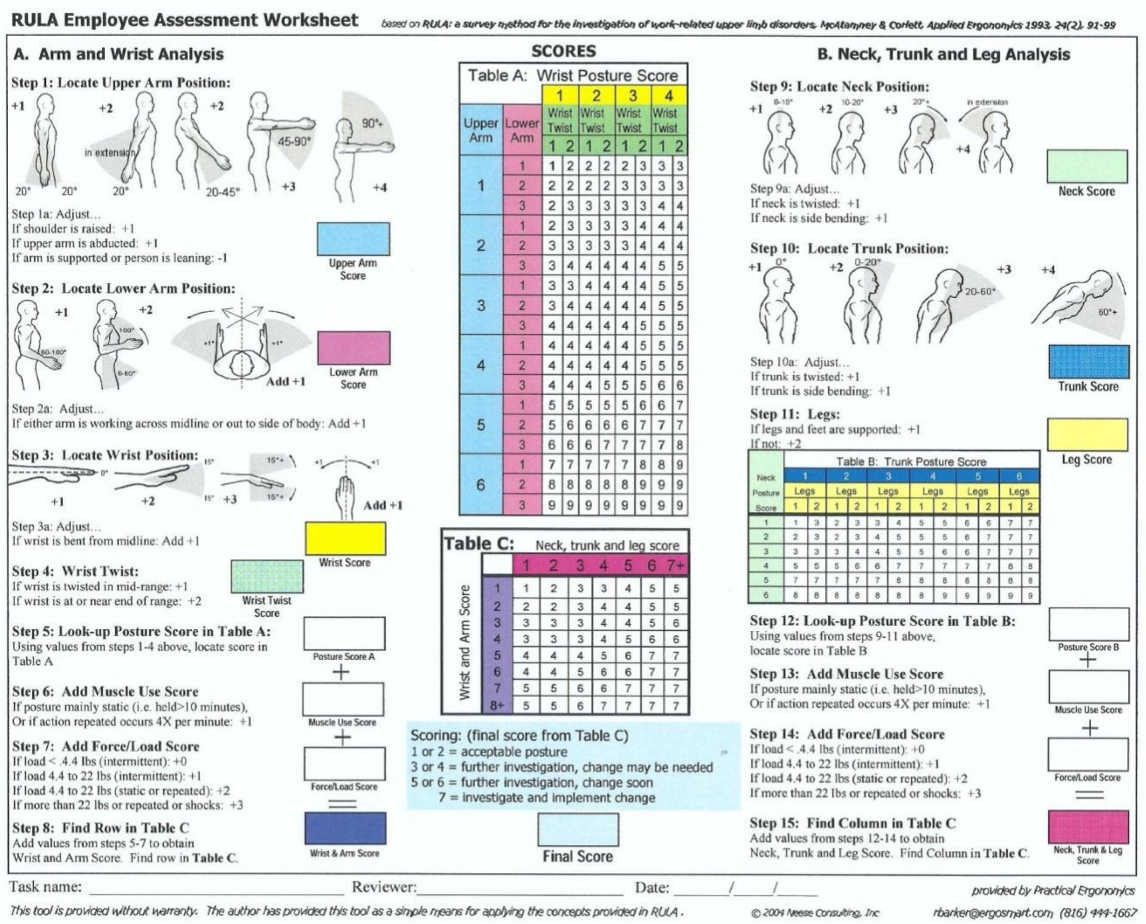
In conclusion, the RULA tool is more suitable to provide a rapid assessment of the posture, muscle functions, and forces that were applied. Figure 2.3 shows the Rapid Upper Limb Assessment (RULA).



Source from McAtamney and Corlett (1993)

Figure 2.3 Rapid Upper Limb Assessment (RULA)

2.3.3 Posture, Activity, Tools & Handling (PATH)

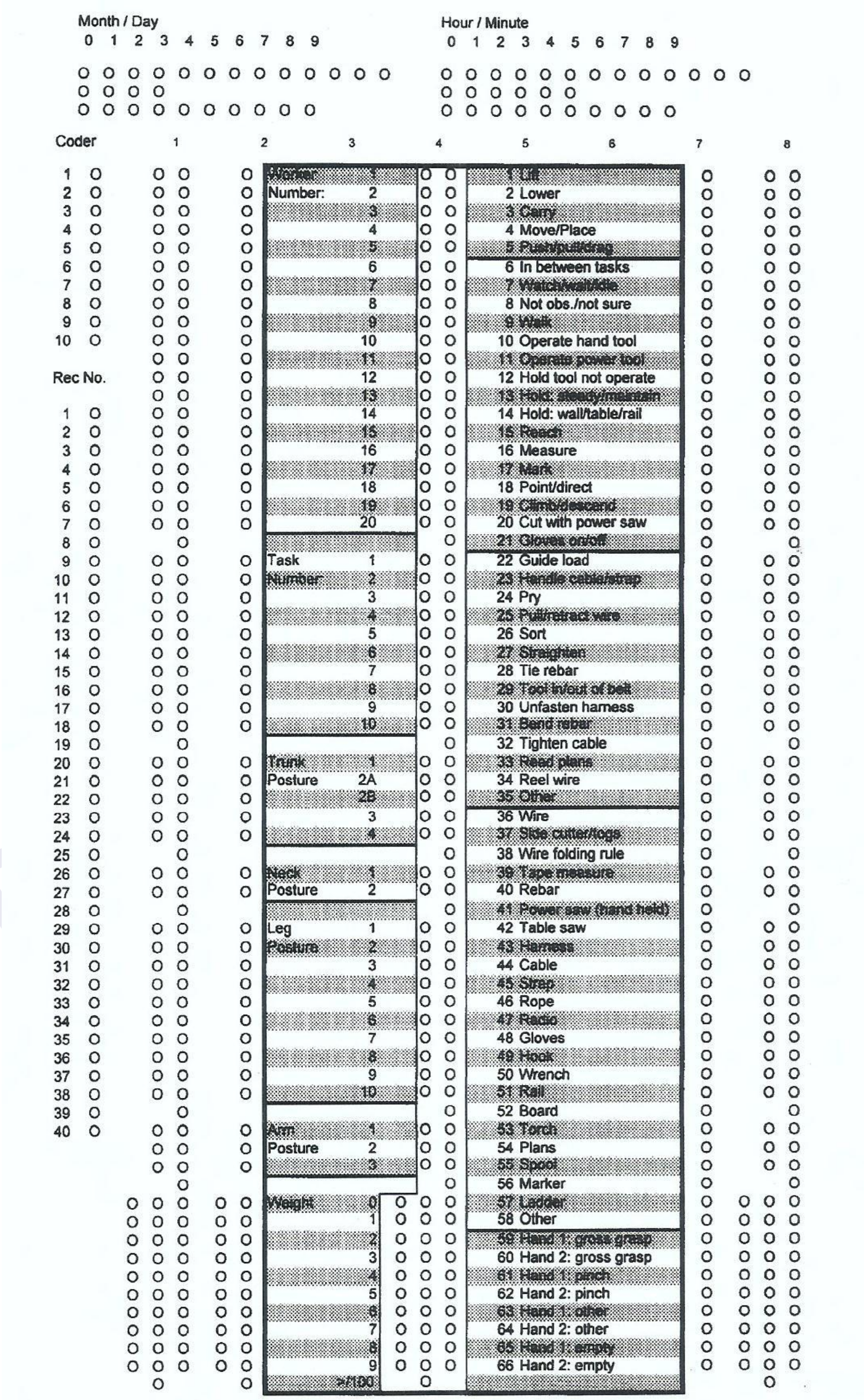
A work sampling-based tool known as the Posture, Activity, Tools & Handling (PATH) tool has been developed to characterized the ergonomic hazards present in highway construction work (Buchholz *et al.*, 1996). The PATH tool has been specifically developed for the construction and agriculture industries and can easily be applied to non-repetitive work.

This method used a digit-code to describe a whole body posture. The coding system was based on a modification of the Ovako Work Posture Analysing System (OWAS) coding system, which described the activity of the worker, the type of the tool used, the size or type of handles and hand grasping. These also encompass the basics of posture code of the PATH method. The range of risk factors covered includes postures and forceful exertion.

During the development process, the results of the PATH analysis were compared with simulated real time analysis in order to determine the validity of the posture codes. For recording the postures of the back and shoulders, a simulated real time analysis method has been developed. There are two sections of work collection segments in the PATH tool: the manual material handling activities and the construction activities. In addition, a simulated real time method was established to define the codes of PATH trunk postures.

Multiple training sessions have been conducted to establish the reliability of the PATH tool; these include the exercises, coding sheets and templates practice, a two-dimensional mannequin and other visual aids. The participants were first introduced to an overview of the construction taxonomy and the PATH method. Next, the participants were taught about the PATH posture codes and were asked to apply the PATH posture codes to still photographs. This task was to be completed with the 5 seconds of observation time while coding the video was performed in real time. The participants were coding the postures of workers at the construction site in real time. Inter-observer agreement has been evaluated based on the coding posture of the workers, which was performed simultaneously by the trainees and experienced observers during the real-time coding.

In conclusion, the PATH tool was developed to analyse the ergonomic risk factors and focused on posture and forceful exertion in the highway construction scenario. Figure 2.4 shows the Posture, Activity, Tools & Handling (PATH) tool.



Month / Day
0 1 2 3 4 5 6 7 8 9

Hour / Minute
0 1 2 3 4 5 6 7 8 9

Coder
1 2 3 4 5 6 7 8 9 10

Rec No.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

1 2 3 4 5 6 7 8

Worker Number: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Task Number 1 2 3 4 5 6 7 8 9 10

Trunk Posture 1 2A 2B 3 4

Neck Posture 1 2

Leg Posture 1 2 3 4 5 6 7 8 9 10

Arm Posture 1 2 3

Weight 0 1 2 3 4 5 6 7 8 9 >/100

1 Lift
2 Lower
3 Carry
4 Move/Place
5 Push/pull/drag
6 In between tasks
7 Watch/wait/idle
8 Not obs./not sure
9 Walk
10 Operate hand tool
11 Operate power tool
12 Hold tool not operate
13 Hold: steady/maintain
14 Hold: wall/table/rail
15 Reach
16 Measure
17 Mark
18 Point/direct
19 Climb/descend
20 Cut with power saw
21 Gloves on/off
22 Guide load
23 Handle cable/strap
24 Pry
25 Pull/retract wire
26 Sort
27 Straighten
28 Tie rebar
29 Tool in/out of belt
30 Unfasten harness
31 Bend rebar
32 Tighten cable
33 Read plans
34 Reel wire
35 Other
36 Wire
37 Side cutter/togs
38 Wire folding rule
39 Tape measure
40 Rebar
41 Power saw (hand held)
42 Table saw
43 Harness
44 Cable
45 Strap
46 Rope
47 Radio
48 Gloves
49 Hook
50 Wrench
51 Rail
52 Board
53 Torch
54 Plans
55 Spool
56 Marker
57 Ladder
58 Other
59 Hand 1: gross grasp
60 Hand 2: gross grasp
61 Hand 1: pinch
62 Hand 2: pinch
63 Hand 1: other
64 Hand 2: other
65 Hand 1: empty
66 Hand 2: empty

Source from Buchholz *et al.* (1996)

Figure 2.4 Posture, Activity, Tools & Handling (PATH)

2.3.4 Rapid Entire Body Assessment (REBA)

The Rapid Entire Body Assessment (REBA) tool was developed and specifically designed for analysing the unpredictable working postures in healthcare and other service industries (Hignett and McAtamney, 2000). The evaluation of the exposure risk factors was based on the diagram of body postures and three scoring tables were provided. In this method, posture and forceful exertion risk factors are covered. Three stages were involved in the development of the REBA: the working posture recording, scoring system development and development of the scale of action levels, which provided the level of risk and further actions to be taken.

More than 14 professionals were involved in gathering and coding over 600 working postures of workers in the health care, manufacturing and electricity industries during two training sessions in order to test the reliability of the REBA tool. Refining the REBA method and starting an analysis of inter-observer reliability for the body part coding were the main objectives of this training. As a result, the inter-observer reliability was at 85% agreement. The REBA tool needs further validation, even though it was defined as a useful tool to analyse postures. This is because no formal studies have been conducted for to test the validity of this tool during the development process. Figure 2.5 shows the Rapid Entire Body Assessment (REBA).

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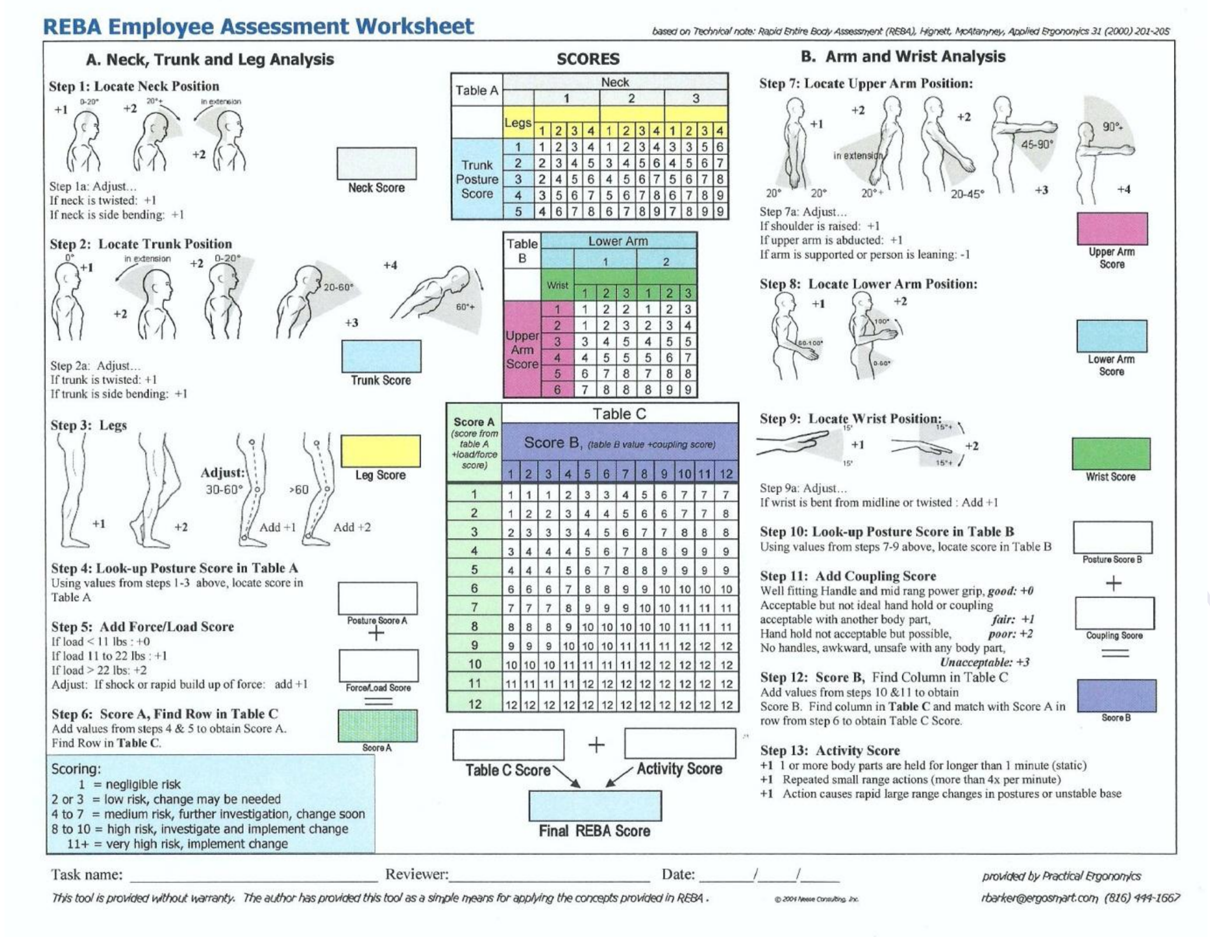

Source from Hignett and McAtamney (2000)

Figure 2.5 Rapid Entire Body Assessment (REBA)

2.3.5 Postural Loading on the Upper-Body Assessment (LUBA)

Postural Loading on the Upper-Body Assessment (LUBA) was developed as a survey method for gathering data on the discomfort ratio value of body parts corresponding to the task duration in static postures (Kee and Karwowski, 2001)

During the development process, the validity of the LUBA tool was tested by 20 male subjects who participated in the experiment. The tool measured the pain or discomfort reported. To gather the data of the subjects' discomfort in a wide range of body motions, the free modulus technique was used in the experiment. Based on the levels of angular deviations from regular joint motions, the scheme of postural classification was developed. The postures were grouped into several categories defined by the results of the same degrees of discomfort in statistical analysis. In this study, the reference point was determined by the relationship of the lowest score of numerical discomfort to the score of discomfort for the elbow flexion. Four categories of different actions have been proposed as criteria to evaluate postural stress during work in order to enable practitioners to make the necessary corrections.

In conclusion, the LUBA tool was developed based on experimental data that analysed postural discomfort depending on the task duration in static postures. However, no formal studies have been conducted to test the reliability of this tool during the development process. Figure 2.6 shows the Postural Loading on the Upper-Body Assessment (LUBA).

Department: Task: Operator:

Analyst name: Date:

Joint	Motion	Class	Score	Motion	Class	Score
Wrist	Flexion	0-20°	1	Extension	0-20°	1
		20-60°	4		20-45°	5
		>60°	9		>45°	11
	Radial deviation	0-10°	1	Ulnar deviation	0-10°	1
		10-30°	5		10-20°	5
		>30°	10		>20°	9
Elbow	Flexion	0-45°	1	Supination	0-90°	3
		45-120°	3		>90°	9
		>120°	7			
	Pronation deviation	0-70°	3			
		>70°	9			
Shoulder	Flexion	0-45°	1	Extension	0-20°	1
		45-90°	5		20-45°	7
		90-150°	9		45-60°	12
		>150°	14		>60°	16
	Adduction	0-10°	1	Abduction	0-30°	1
		10-30°	4		30-90°	6
		>30°	11		>90°	13
	Medial rotation	0-30°	1	Lateral rotation	0-10°	1
		30-90°	4		10-30°	5
		>90°	10		>30°	10
Neck	Flexion	0-20°	1	Extension	0-30°	1
		20-45°	5		30-60°	9
		>45°	8		>60°	15
	Lateral bending	0-30°	1	Rotation	0-30°	1
		30-45°	5		30-60°	4
		>45°	13		>60°	11
Back	Flexion	0-20°	1	Extension	Not included	
		20-60°	6			
		>60°	13			
	Lateral bending	0-10°	1	Rotation	0-20°	1
		10-20°	5		20-30°	3
		20-30°	12		30-45°	7
		>30°	16		>45°	14

Postural load =

Source from Kee and Karwowski (2001)

Figure 2.6 Postural Loading on the Upper-Body Assessment (LUBA)

2.3.6 Quick Exposure Checklist (QEC)

David *et al.* (2008) have developed an observational tool called the Quick Exposure Checklist (QEC) to evaluate the ergonomics risk factors related to work-related musculoskeletal disorders (WMSDs). Development of the QEC tool involved two phases in which a total of 206 practitioners participated in order to test, modify and validate this tool using simulated and real workplace tasks. The QEC tool assesses the four main body areas and involves practitioners and employees in the assessment.

During the development process in Phase 1, the validity of the QEC tool was tested by 18 practitioners using the QEC tool to assess four task simulations which were compared to the results of the SIMI 3D computerised motion analysis by experts. The validation was also conducted by comparing the scores of six practitioners with expert assessments using the QEC tool (Li and Buckle, 1999a; Li and Buckle, 1999b). In Phase 2, the validity test was conducted at six organisations and five tasks were assigned to each organisation. Seven practitioners with two experts from the group assessed the each job (David *et al.*, 2005).

In Phase 1, the reliability of QEC was based on comparison of the variation task score conducted by practitioners with the results of SIMI 3D computerised motion analysis by experts (Li and Buckle, 1999a; Li and Buckle, 1999b). Eighteen practitioners viewed the video recordings of 18 industrial static and dynamic activities, including the combination of repetitive and forceful characteristics in seated and standing participants. In Phase 2, the inter-observer reliability was designed to complement the trial results in Phase 1 using video film of the jobs (David *et al*., 2005).

Training on the QEC assessment involved six practitioners who performed QEC assessment on the small range of the tasks in the workplace. The trial assessment was focused on simulated tasks to familiarize the trainees with the QEC tool and to facilitate discussion with the experts. The practitioners were observed and evaluated on the three tasks involving laboratory work using the QEC tool.

In conclusion, evaluation of the reliability and validity of the QEC tool is the most important part of the development of the QEC tool in Phase 1. The risk assessment method using video film showed that the observer-reliability of QEC had 'fair to moderate' levels of agreement. In Phase 2, the evaluation of inter-observer

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